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DIRECT MEASUREMENTS OF TROPOSPHERIC OZONE

FROM TOMS DATA

NAGW - 2696

PROGRESS REPORT

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Introduction

In the past year we have made measurements of the tropospheric total column of ozone during the biomass burning season in Africa. (August to October) .Fishman et. al. had reported previously that by taking a time average of the low spatial resolution data from TOMS (Total Ozone Mapping Spectrometer) on NImbus-7 (referred to as the Grid-T data set), that during the Biomass burning season in Africa (August to October), a plume of ozone extends from the East coast of Africa into the Atlantic. In this report we present an analysis that we have made using the measured TOMS radiances taken from the High Density TOMS data set (referred as the HDT data set), which examines this plume in more detail.

Analysis technique

We have re-analyzed the measured radiances for two specific cases, (1) those measured above the marine stratocumulus cloud bank that is a persistent feature off the East coast of Africa during the period of biomass burning, (2) those measured above non-cloudy regions over the African continent .

Figure 1a shows a plot of the total ozone taken from the archived HDT data as a function of latitude and longitude near the east coast of Africa for October 15 1989. Figure 1b is a plot over the same region of the measured surface reflectivity from the same data set. There is an obvious correlation between the two quantities, especially above the cloud base. There are three factors that account for this correlation. The first is that the cloud height assumed in the TOMS algorithm is a mean climatological height . Figure 2 shows a plot of this climatological cloud height versus latitude. At the latitudes shown in Figure 1 this mean height is near 300 mb, whereas the measured height of the marine stratocumulus cloud is about 800 mb. In Figure 3 we have calculated the effect of this assumption on the retrieved total ozone. It will cause the archived results over the cloud to be too high.

The second factor is more subtle. In general TOMS tends to underestimate the amount of tropospheric ozone over and above the climatological amount assumed in the standard profiles which are used to generate the look-up tables for the algorithm. This is especially true over regions of low reflectivity. This underestimate arises because the scattered radiance observed by the instrument is the sum of the scattered radiance from the atmosphere and the reflected radiance from the surface. For low reflectivity surfaces, e.g the earth's surface or over the ocean, the contribution of the scattered radiance dominates. If the additional tropospheric ozone is distributed at low altitudes then some of the measured radiance will not have passed through the total column of ozone and the algorithm will underestimate the additional ozone. However, over high reflectivity clouds the reflected radiance dominates over the scattered radiance, and the derived total ozone amount is close to the actual amount. We say close, because ,in general, the algorithm will tend to overestimate the column amount due to multiple scattering just above the cloud..

The third factor is not as universal as the other two. The present TOMS algorithm assumes that any surface that has a measured reflectivity between 0.2 and 0.6, is the result of partial cloud cover. The algorithm uses a formula that expresses this reflectivity as an actual reflectivity of 0.6 but assumes a lower cloud altitude, i.e. in the case that we have chosen, at a cloud height corresponding to a higher pressure that 300 mb. It then uses this cloud height in the look-up table procedure. However when we examine the visible cloud images for this day we cannot detect broken clouds, and it is our conclusion that clouds can have reflectivities down to at least 0.4.

Figure 1c shows the results of an analysis of the TOMS radiances for the same region as in Figure !a, for that data taken above the cloud base. We have limited the analysis to reflectivities above 0.4, and have assumed that the cloud has a solid base. We also used a look-up table approach, but the tables used were generated for the particular measured cloud height. The resultant total ozone map differs substantially from that in the archives, but shows a latitude dependence which is similar to the archived total ozone for the same day for a region over the Indian Ocean, where no clouds were observed. From this similarity we conclude that the new analysis of the data appears to give a more realistic result.

In order to derive the tropospheric total ozone amount, we now have to subtract the amount of ozone in the stratosphere. We have used two methods to do this. In the first we used the fact that the results over the Indian Ocean were similar in general structure to those over the cloud base. If we make the assumption that any ozone resulting from the biomass burning will travel East, then we can argue that the total ozone measured above the Indian Ocean, will be a surrogate for the stratosphere ozone amount if we take into account the small amount of climatological tropospheric ozone. In essence we are assuming that the stratospheric ozone is constant along any given latitude band.

In the second method, we assumed that the variation of total ozone along a latitude band was due only to the displacement of the tropopause. The variation of the tropopause height was obtained from the NMC analysis, and the relation between the tropopause height and total ozone was obtained from the data over the Indian Ocean.

The next region we examined was that over the African continent. In this case we did not have accurate cloud height data, and there was some evidence that many of the clouds were at heights above 500 mb, i.e. above the ozone from the biomass burning. We therefore decided to examine data only from cloud free regions (reflectivities less than 0.2). As discussed earlier, for data obtained over regions of low reflectivity, the TOMS algorithm will underestimate tropospheric ozone over and above the climatological value used in the tables. Figure 4 shows the efficiency of retrieval for tropospheric ozone as a function of the height of the additional ozone for observations in the nadir direction.

TOMS achieves it's contiguous coverage by scanning in a plane perpendicular to the orbital plane,. The scan angle varies from +53 degrees to -53 degrees. We have found that the efficiency for detection of troposphere ozone is not only a function of altitude but also of the scan angle. Figure 5 shows the efficiency for ozone at altitudes of 500 and 700 mb as a function of the scan angle.. The actual value of the scan angle is a function of the attitude of the spacecraft, and this information is not given on the HDT tapes. However this information can be found on the TOMS Raw Unit data tapes (RUT Tapes). Herman et. al. point out that there is an error in the derived altitude angles given on these tapes, which introduces an effective roll error in the scan angles. Unfortunately this correction is not given on the RUT Tapes. We are grateful to C. Wallermeyer for supplying us with the correction for the days that we have analyzed.

The final data we need to correct the derived tropospheric ozone from the archived data, are profiles for the ozone resulting from the biomass burning. We have used the profiles recently published by Fishman et. al. These authors give several profiles, but the calculated efficiencies for each profile of ozone retrieval vary by only a few per cent..

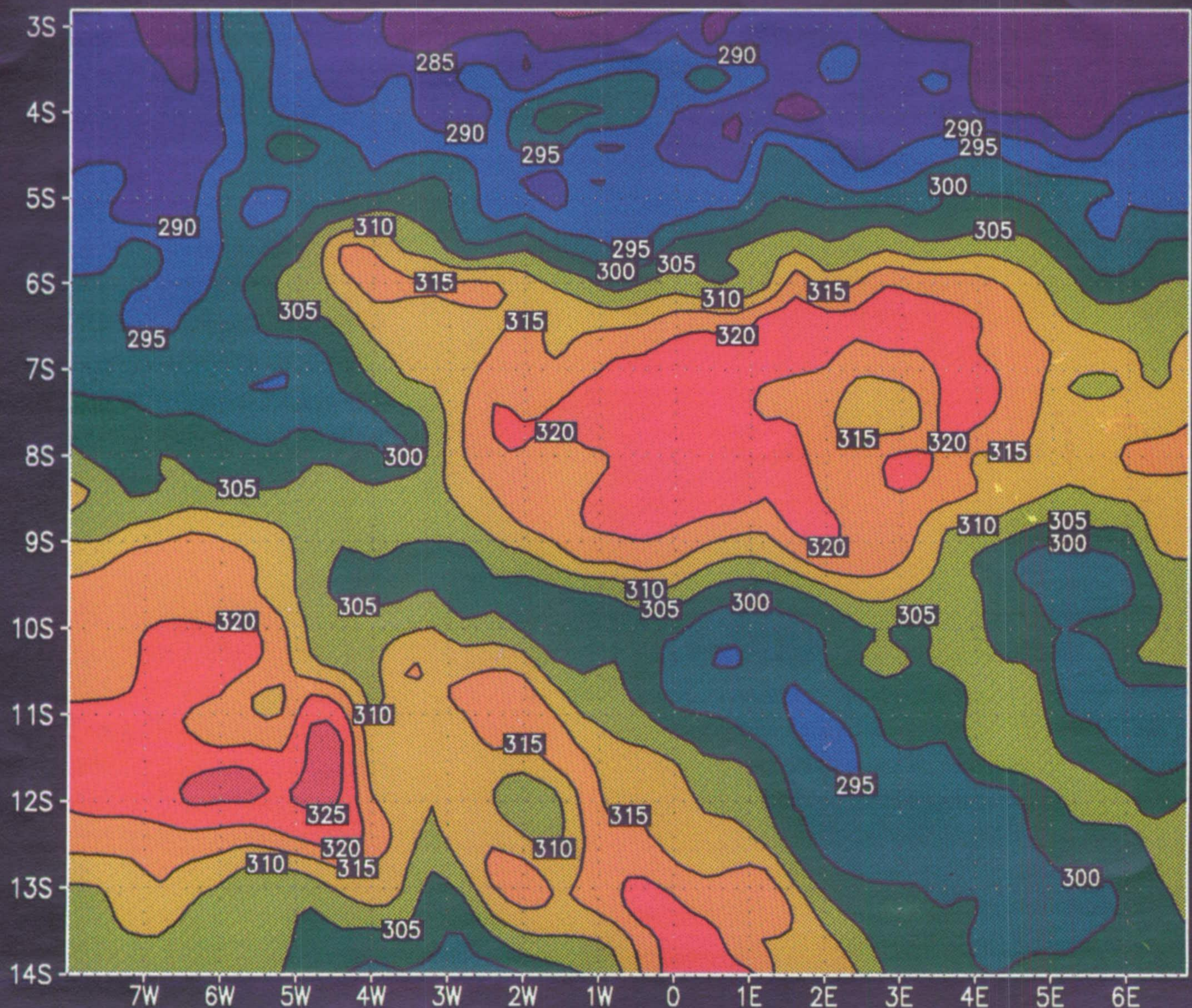
The preliminary results of this analysis show that rather than a continuous plume as deduced by Fishman et. al., the plume consists of clouds of ozone that move with the wind profiles at about 500 mb. We supplied the TRACE-A mission this year with an analysis of the TOMS real-time HDT data (Provided for the Antarctic ozone hole survey) using these new techniques, and preliminary results from the aircraft mission agree well with our analysis.

Future Work

During the next year we intend to continue our analysis of the tropospheric ozone fields over the African continent. Given the time, we intend to supply the TRACE-A investigator team with better tropospheric ozone fields for the times of their mission. Our goal is to provide a continuous field over the continent and the Indian and Atlantic Oceans. With this data we can then follow the formation of the ozone clouds, and hopefully provide an estimate of the contribution of the biomass burning to the ozone budget of the troposphere.

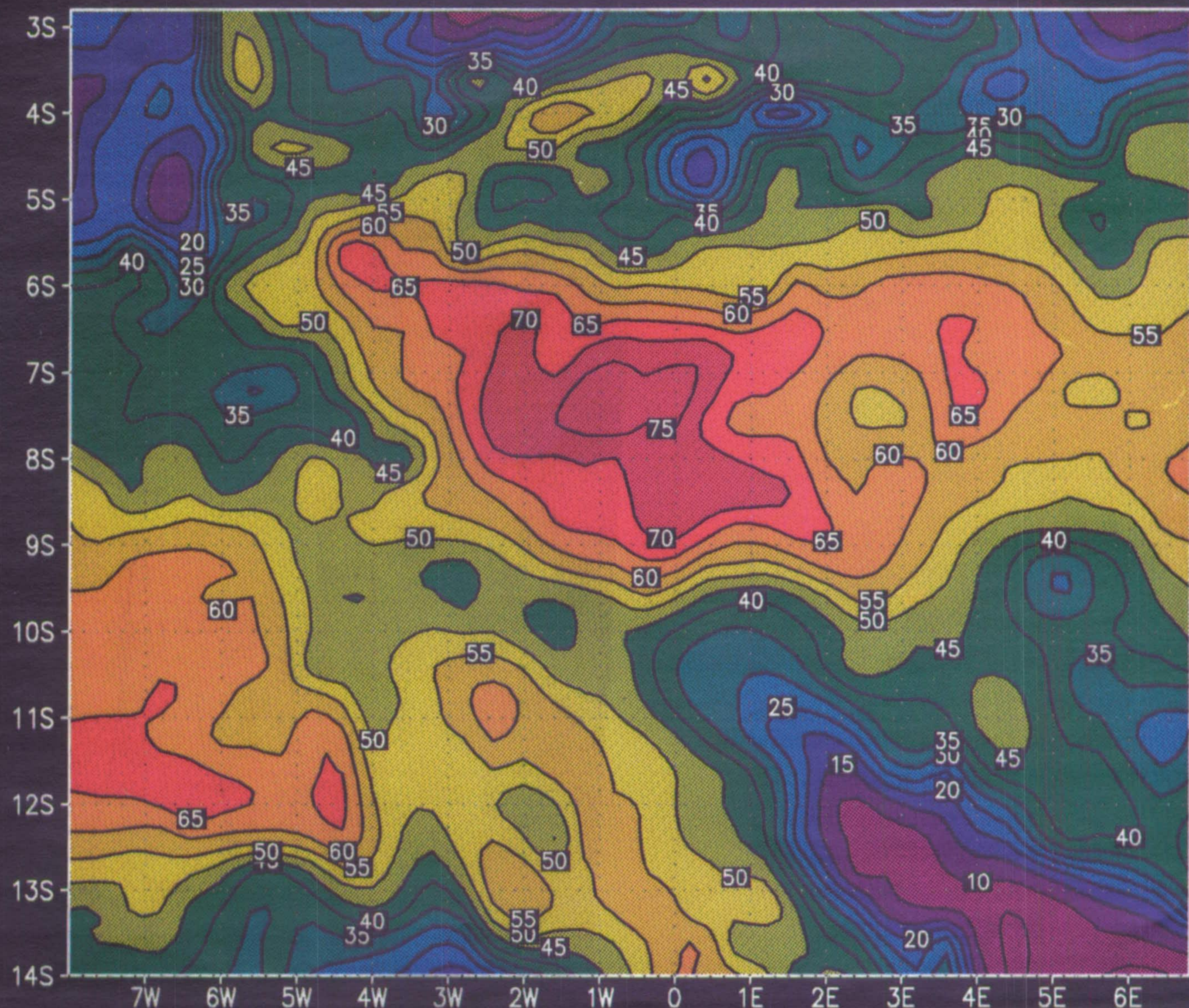
The analysis discussed above has general significance, and we will also examine HDT data off the coast of South America during the biomass burning in the Amazon basin, and over the Los Angeles basin.

Uncorrected Total Ozone on Oct 14, 1989

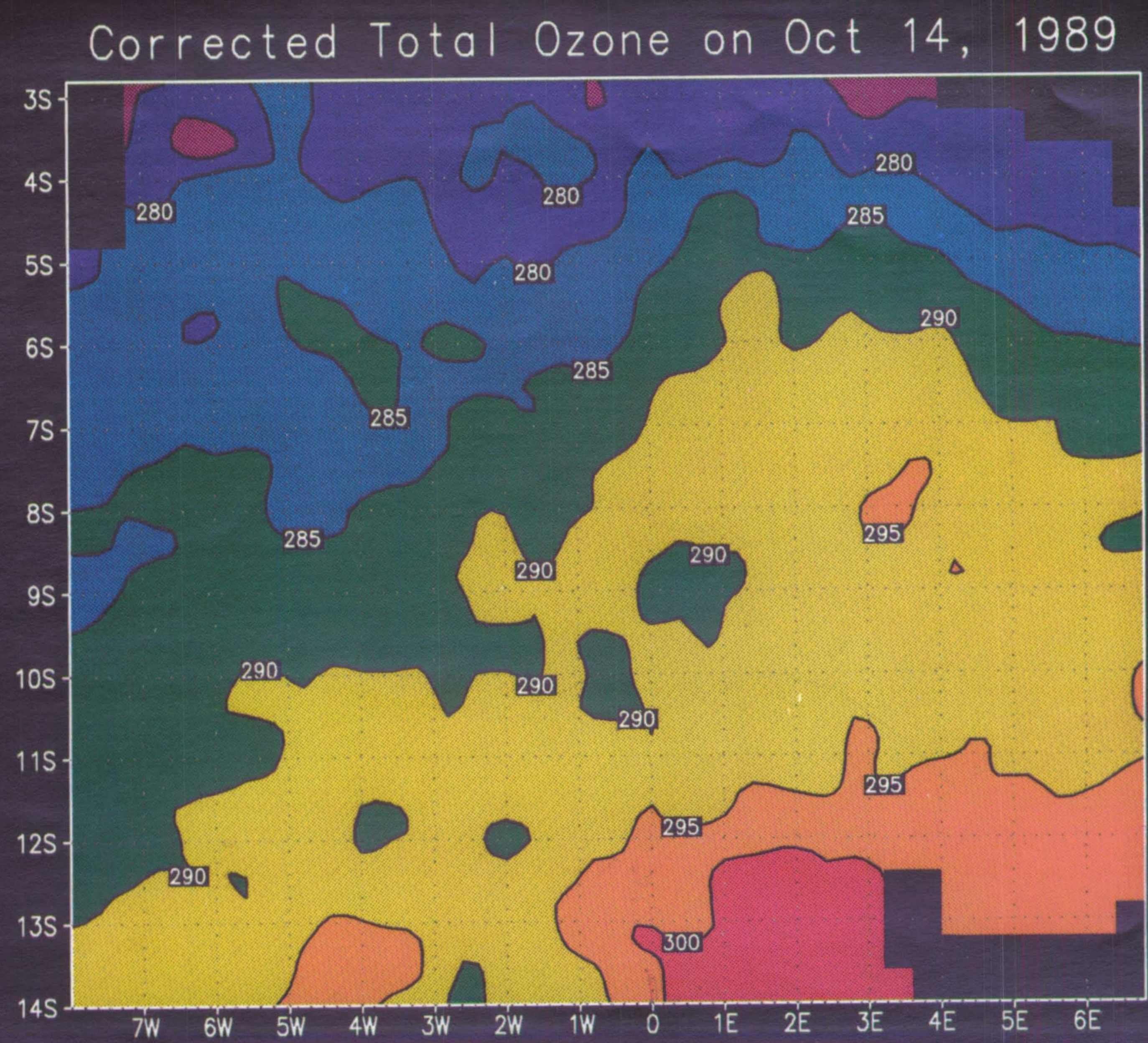


1 - A

Reflcitivity on Oct 14, 1989



1 - B


Corrected Total Ozone on Oct 14, 1989
3S
4S
5S
6S
7S
8S
9S
10S
11S
12S
13S
14S
7W
6W
5W
4W
3W
2W
1W
0
1E
2E
3E
4E
5E
6E
280
285
290
295
300

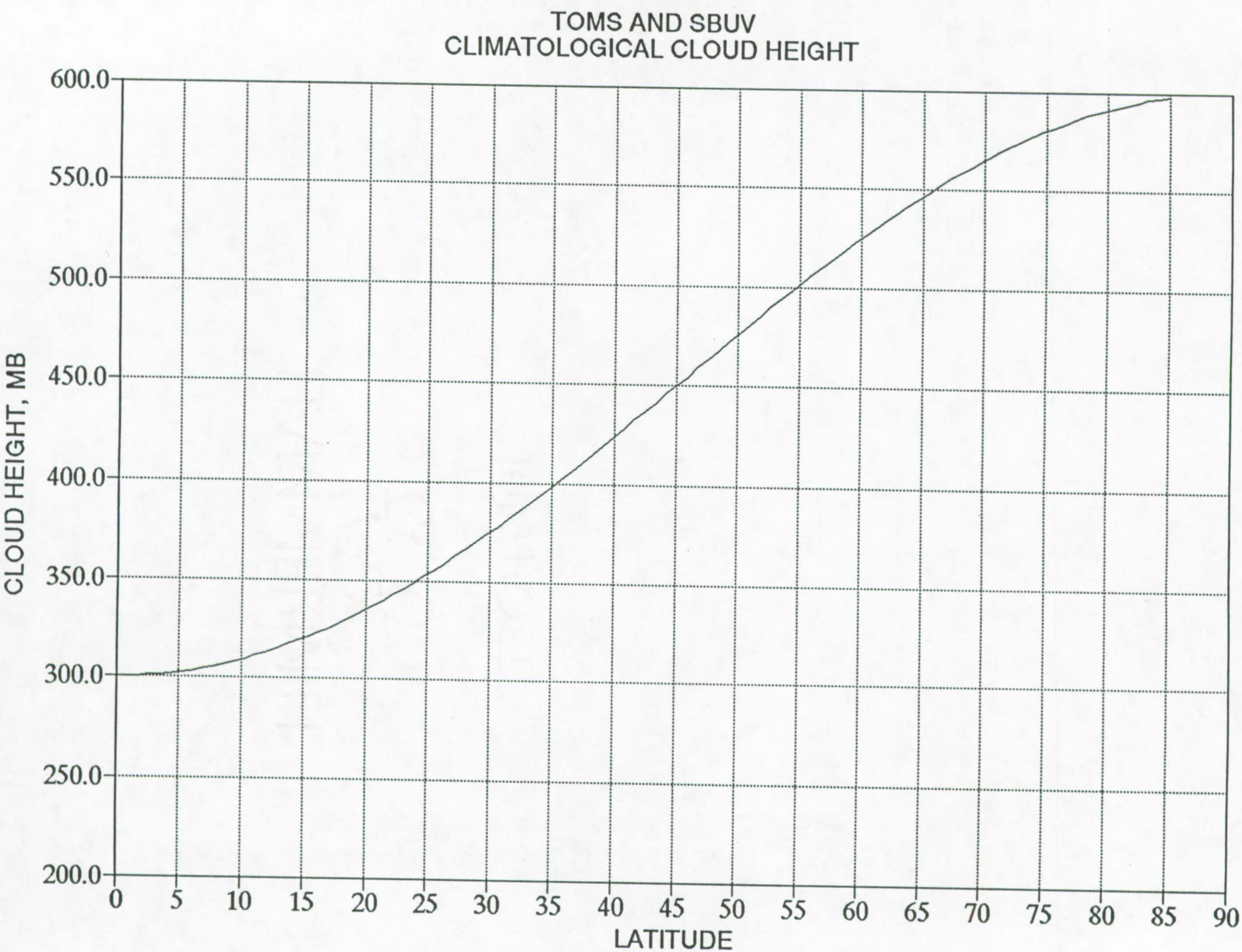
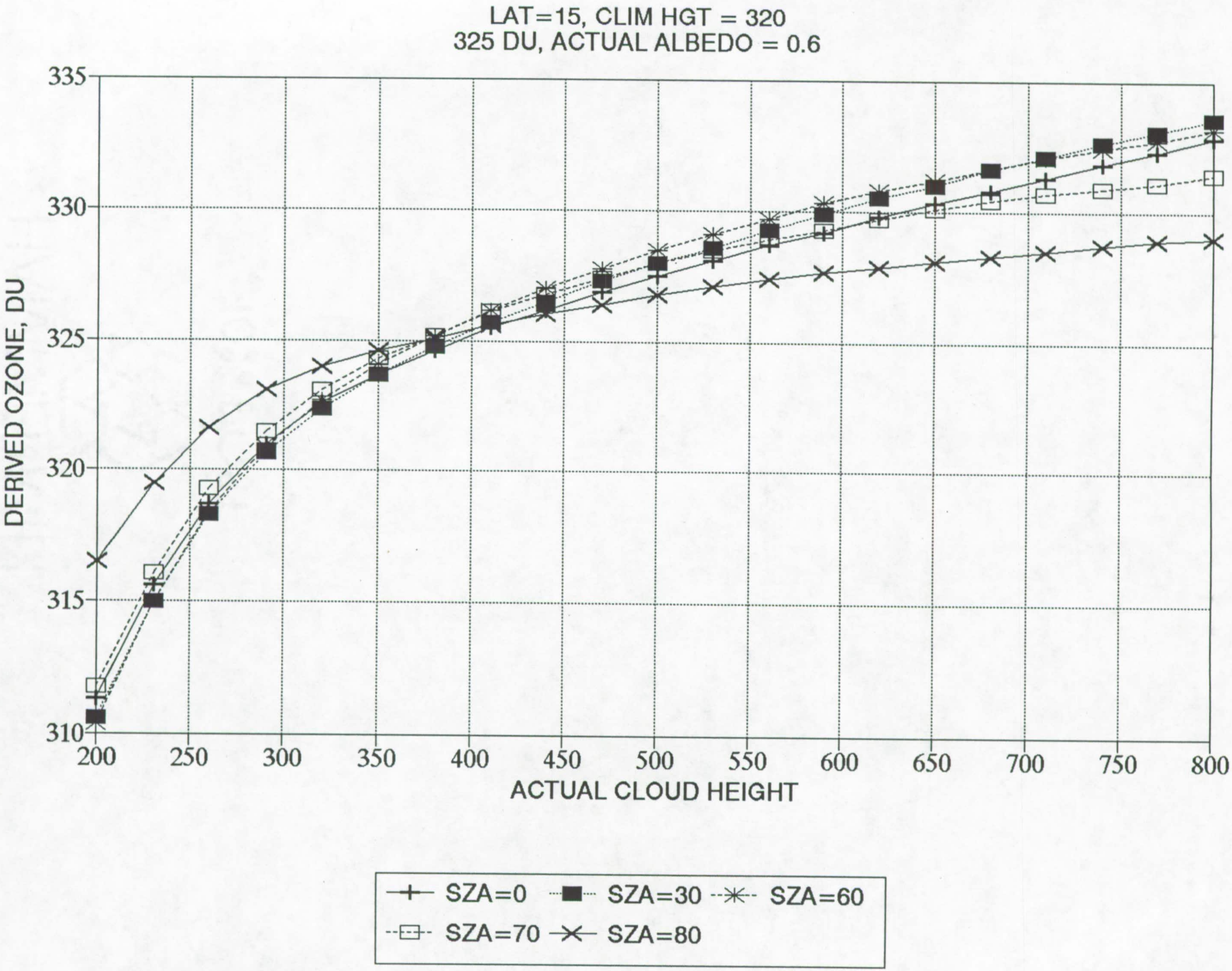

TOMS AND SBUV
CLIMATOLOGICAL CLOUD HEIGHT
CLOUD HEIGHT, MB
600.0
550.0
500.0
450.0
400.0
350.0
300.0
250.0
200.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
LATITUDE

FIG. 2



LAT=15, CLIM HGT = 320
325 DU, ACTUAL ALBEDO = 0.6
DERIVED OZONE, DU
335
330
325
320
315
310
200
250
300
350
400
450
500
550
600
650
700
750
800
ACTUAL CLOUD HEIGHT
SZA=0
SZA=30
SZA=60
SZA=70
SZA=80

FIG. 3

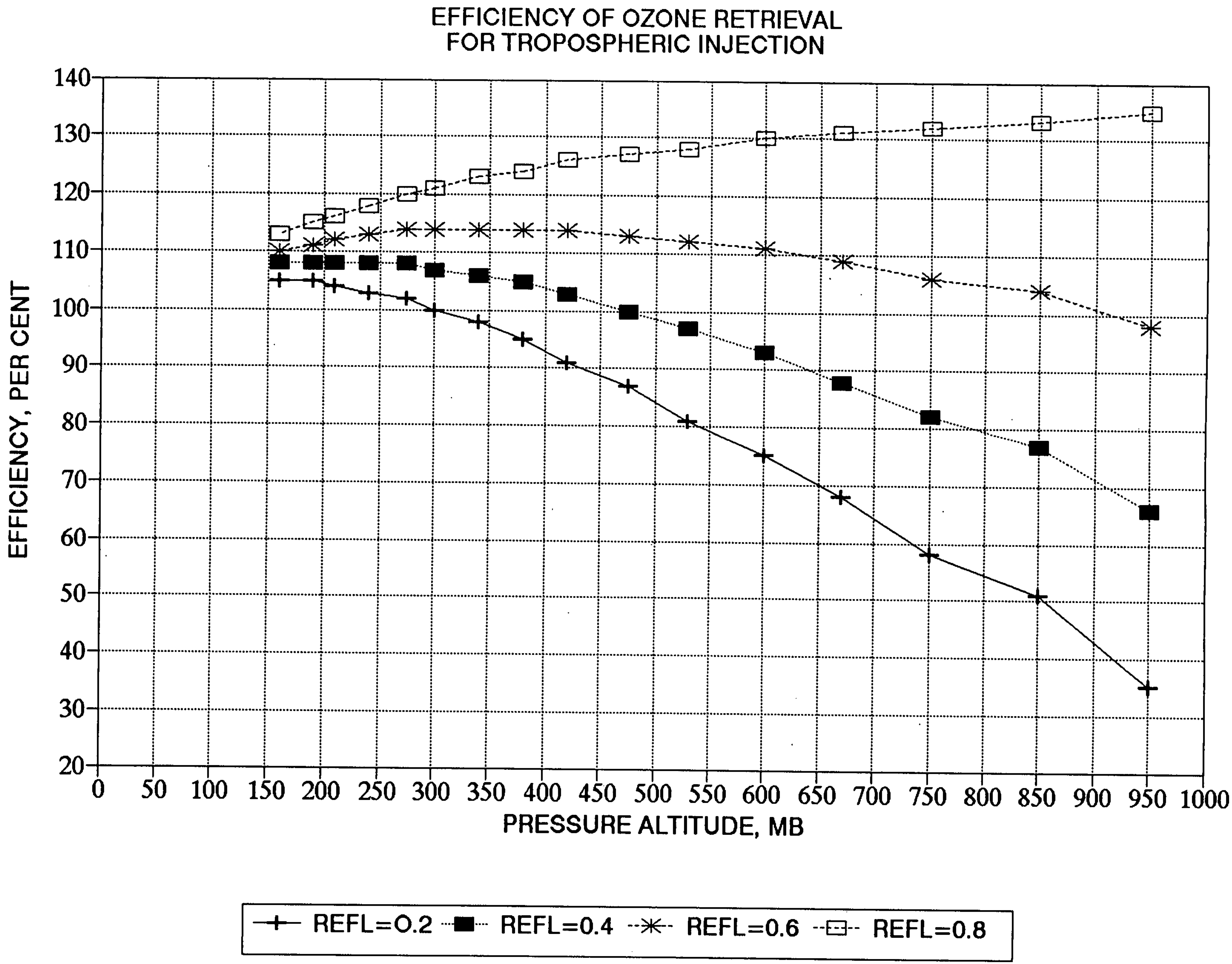

EFFICIENCY OF OZONE RETRIEVAL
FOR TROPOSPHERIC INJECTION
EFFICIENCY, PER CENT
140
130
120
110
100
90
80
70
60
50
40
30
20
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
PRESSURE ALTITUDE, MB
REFL=O.2
REFL=0.4
REFL=0.6
REFL=0.8

FIG. 4

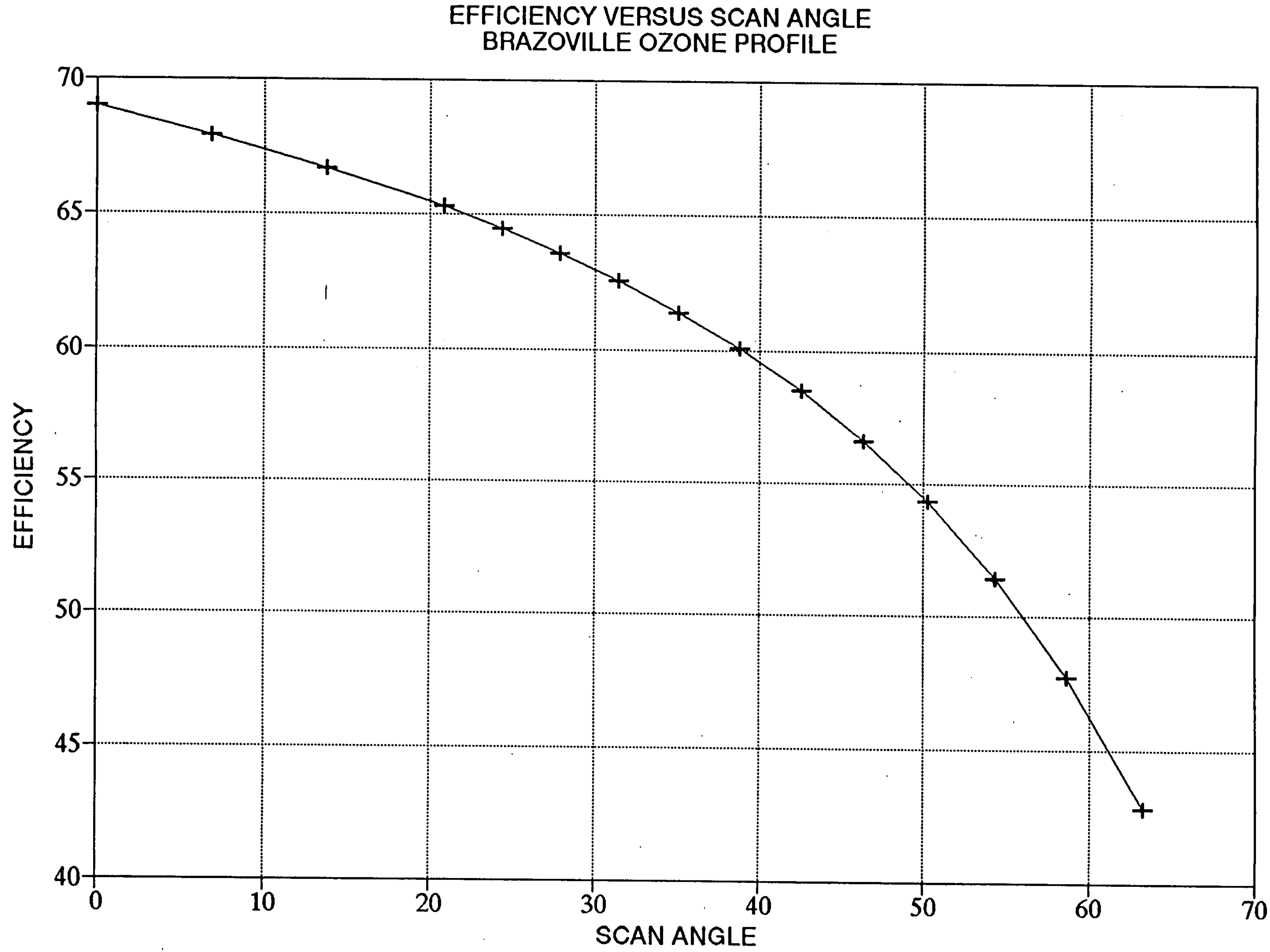

EFFICIENCY VERSUS SCAN ANGLE
BRAZOVILLE OZONE PROFILE
EFFICIENCY
SCAN ANGLE
70
65
60
55
50
45
40
0
10
20
30
40
50
60
70

FIG. 5

PROPOSED BUDGET
PERIOD: 02/01/93–01/31/91

07–Jan–93

I. PERSONNEL	
RESEARCH ASSOCIATE (6 MOs)	$18,375
	0
GRA LEVEL II(MOs)	12,814
SECRETARIAL	0
PROGRAMMER	0
UNDERGRADUATE	1,064
TOTAL SALARY AND WAGES	32,253
II. FRINGE BENEFITS	11,131
III. TRAVEL	
DOMESTIC	3,150
FOREIGN	2,500
TOTAL TRAVEL	5,650
IV. EQUIPMENT	
DEC W/S (PARTIAL)	4,500
1.3 GB DEC DISK STORAGE	2,500
	0
	0
	0
	0
TOTAL EQUIPMENT	7,000
V. OTHER DIRECT COSTS	
TEL/COPYING/POSTAGE	1,000
	0
COMPUTER MAINT.	750
PUBLICATION COSTS	2,500
RESEARCH MATERIALS	1,000
OFFICE SUPPLIES	532
TOTAL OTHER DIR COSTS	5,782
TOTAL DIRECT COSTS	61,816
VI. INDIRECT COSTS	
45.8% OF TOTAL MODIFIED TOTAL DIRECT COSTS	25,106
TOTAL REQUESTED SUPPORT	$86,922